THE NOW FRONTIER

MAN LINKS EARTH AND PLANETS

PIONEER TO JUPITER

ISSUE NUMBER FOUR
MISSION TO JUPITER

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Pioneer 10 will reach Jupiter on December 3 after a 22-month, 620 million mile trip. It has already set many records. Pioneer traveled faster and further than any other man-made object. Its tremendous launch speed of 32,114 miles per hour from an Atlas-Centaur rocket on March 2, 1972, carried it beyond the Moon in 11 hours. But even this speed will be outdone at the closest approach to Jupiter when that planet's gravity causes Pioneer to hurtle past at 82,000 miles per hour.

Pioneer 10 is the first spacecraft to fly beyond Mars' orbit, the first to cross the Asteroid Belt. It should also be the first man-made device to leave the Solar System entirely and fly off among the stars of the Milky Way, the Galaxy.

And the spacecraft flies with unbelievable accuracy; after nearly two years of flight through space it is scheduled to arrive at Jupiter within less than one minute of the planned time.

A second Jupiter-bound spacecraft, Pioneer 11, was sent after the first on April 5, 1973.

THE SPACECRAFT AND ITS PATH

Pioneer 10 and its companion are the first spacecraft designed to travel into the outer Solar System and to operate there for as long as 7 years and as far from the Sun as 1.5 billion miles, possibly more. For such a mission a spacecraft needs extreme reliability; nothing must fail. And the spacecraft must be lightweight so that its booster rocket can accelerate it to the high speed needed. It must have a communication system that can operate over vast distances, and since it cannot rely on the Sun for power when so far away, it must carry its own nuclear power units.

The two Pioneers are stabilized by rotation, like spinning tops. Both are controlled largely from Earth since on-board computers would be too heavy.

The Pioneers are almost identical. Each is 9½ feet long from the cone-shaped antenna horn sticking out from the dish of the communication antenna, to the other extreme of its structure (Figure 1). The spacecraft's spin axis and the center line of the dish antenna are parallel. Equipment is stored in a flat, hexagonal-shaped box beneath the antenna. Scientific equipment for experiments is housed in a smaller box attached to one side of the larger. Some science equipment is mounted outside of the two boxes.

Two structures of rods extend from the spacecraft to carry nuclear power generators at their ends. These generators convert energy from the atomic breakdown of Plutonium-238 into electricity. They are expected to provide power for at least five years after launch.

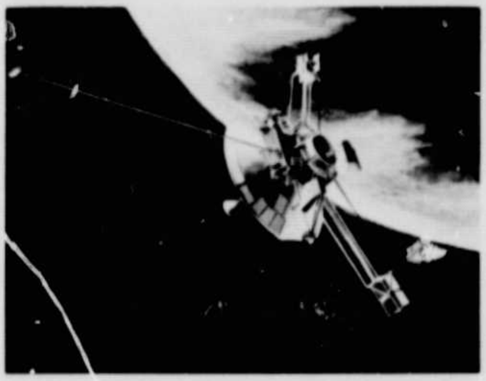

Figure 1. Pioneer Jupiter Spacecraft

A third, single rod extension carries more scientific equipment. All the booms were extended in flight after launching.

Small rocket jets change the velocity of the spacecraft, change its attitude, or change its speed of rotation. They are controlled by commands from Earth or automatically by commands stored in the spacecraft's electronic memory. An automatic system also uses these thrusters to keep the spin axis, and therefore the communications antenna, pointed directly towards Earth.

The Pioneers follow a curved path to Jupiter—some 620 million miles long covering about 160 degrees around the Sun between the orbits of Earth and Jupiter (Figure 2). About 120 days after launch each Pioneer enters the Asteroid Belt, a zone of small planetary bodies between the orbits of Mars and Jupiter. The largest of these bodies is Ceres, 480 miles in diameter. Most are very much smaller. A planet was probably prevented from forming here because of the influence of Jupiter, and astronomers thought that the region might be strewn with high velocity debris down to the size of specks of dust. The number of small particles was unknown and could have presented a major hazard to spacecraft traveling to the outer planets.

Almost 300 days after launch, Pioneer 10 passed on the far side of the Sun from Earth. Radio communication was interrupted for a few days.

With Pioneer 10 well on its way through the Asteroid Belt without incident, the second spacecraft, Pioneer 11, was launched on a very similar path to Jupiter. Leaving April 5, 1973, it is scheduled to arrive at Jupiter a year after Pioneer 10, namely in December, 1974. Its path is ordered so that, depending upon the findings of Pioneer 10, the second Pioneer can fly closer to or further from Jupiter, fly to Saturn in 1980, or follow Pioneer 10 out of the Solar System.

WHAT THE SPACECRAFT DO

Both spacecraft are designed to investigate Jupiter in three ways:

1) measurements of particles, fields, and radiation

2) television imaging to provide pictures of the planet and several of its satellites

3) accurate observation of the path of the spacecraft to measure the forces (such as the gravity of Jupiter) acting upon it.

The spacecraft also provides information on interplanetary space from the Earth's orbit to the orbit of Saturn and beyond.

A number of experiments have been designed with the objectives listed.

INVESTIGATION OF INTERPLANETARY SPACE ON THE WAY TO AND BEYOND JUPITER

- Map the magnetic field in interplanetary space between Earth's orbit and Jupiter's orbit, and beyond.

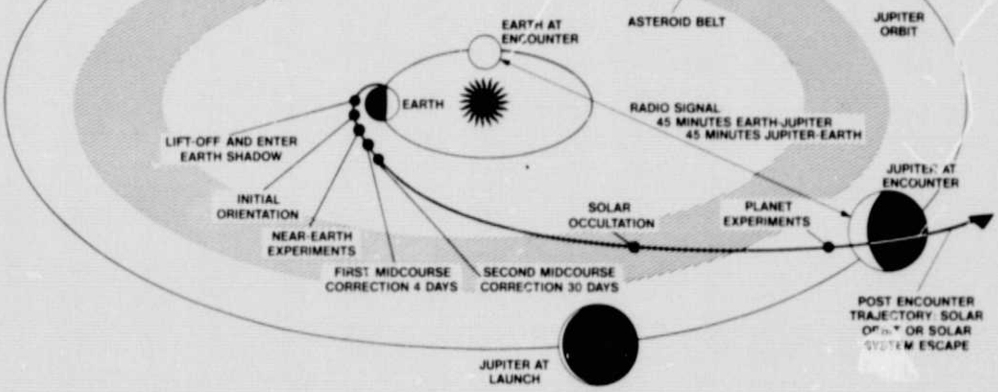

Figure 2. Mission Events

- Determine the changes and the arrival direction of cosmic rays—fast moving parts of atoms—rushing out from the Sun and also into the Solar System from the Galaxy.
- Determine how the solar wind—a flow of charged particles from the Sun—varies with distance from the Sun.
- Ascertain any relationships between the solar wind, the interplanetary magnetic field, and cosmic rays.
- Search for the end of the solar atmosphere (the heliosphere).
- Determine the properties and density of interplanetary dust.

INVESTIGATION OF THE JOVIAN SYSTEM

- Map the magnetic field of Jupiter.
- Determine the numbers and types of charged particles in the radiation belts of Jupiter, and the extent of these belts.
- Check if Jupiter has auroras like the Earth does (glows in the upper atmosphere over the polar regions).
- Try to find out what causes the decimetric and decametric radio waves from Jupiter.
- Detect and measure a shock wave between the magnetic field of Jupiter and the wind of charged particles from the Sun, like the bow wave of a ship.
- Measure the temperature of the outer atmosphere of Jupiter above the cloud tops.
- Measure the proportions of hydrogen and helium in Jupiter's atmosphere.
- Measure the structure of the planet's visible atmosphere and also of the higher regions where molecules of gases become electrically charged and produce an ionosphere.
- Measure the brightness, color, and polarization (the direction of vibration) of reflected light from Jupiter.
- Photograph Jupiter from a distance, and later close to, with better resolution than that obtainable from Earth; obtain pictures of the terminator (the region of sunrise and sunset) and of a crescent Jupiter with the Sun shining from behind the planet.
- Photograph the satellites from a distance, and some of them close-up; measure their sizes and determine which, if any, possess an atmosphere.
- Calculate with greater accuracy the orbits and masses of the satellites and the gravitational field of Jupiter itself.

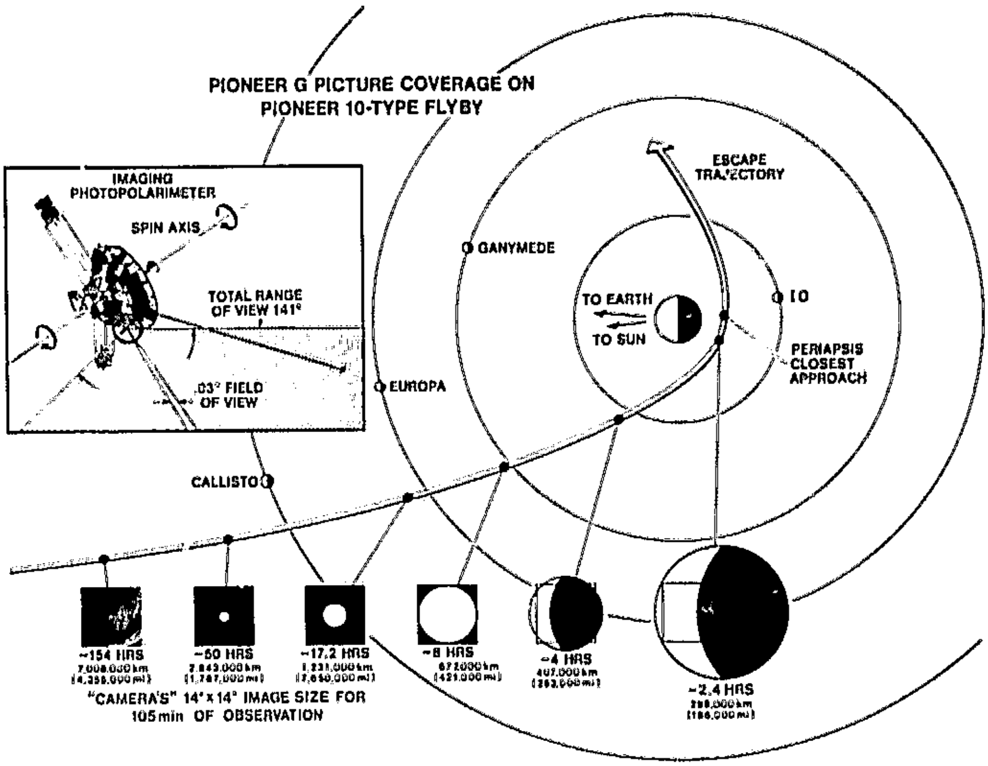

Figure 3. Picture Coverage at Encounter

To achieve these objectives each spacecraft uses a battery of scientific instruments. These include a magnetometer to measure magnetic fields, a plasma analyzer to measure the ions and electrons flowing through space from the Sun (solar wind), a composite device to detect and measure electrons and protons in the radiation belts and nuclei of chemical elements from hydrogen to oxygen, and a cosmic ray telescope to detect and measure cosmic rays.

A geiger tube telescope and a radiation detector also detect and measure particles in the radiation belts.

An asteroid-meteoroid detector measures paths of space particles in the vicinity of the spacecraft to find the distribution of dust and other particles in the space between the planets of the Solar System, and in the vicinity of Jupiter. A meteoroid detector also keeps tags on these particles as they puncture its pressurized cells.

An ultraviolet photometer (light measurer) and an infrared radiometer (heat measurer) look at interplanetary space and the Jovian system in ultraviolet and infrared—the radiation on either side of the visible spectrum of light that extends from violet to red (the colors of the rainbow). The ultraviolet instrument determines how much helium exists in the atmosphere of Jupiter, and how much hydrogen and helium is flowing into the Solar System from the Galaxy. The infrared instrument measures heat radiated from Jupiter and from features such as the Great Red Spot. It also checks the proportions of hydrogen and helium in the atmosphere.

An imaging photopolarimeter moves a narrow beam in sweeps across the surface of Jupiter and builds up a picture like a television set builds its picture by a series of lines across the tube face. The instrument measures the intensity and the polarization (how the light waves are vibrating) of light from Jupiter and its satellites. It is also used to scan space on the way to Jupiter. This instrument, through a computer back on Earth, provides television-type images—pictures of Jupiter that are expected to be better than those obtained by telescopes from Earth and at viewing angles impossible from Earth. Textures and shapes of clouds should be seen.

Pictures also will be constructed of Jupiter's large Galilean satellites. Since radio signals are continuously coming from the spacecraft to Earth, these can be used to probe into the atmosphere of Jupiter and the satellite, Io, by measuring fading of these signals when the spacecraft passes behind Jupiter and the satellite. This experiment provides information about the composition and density of the atmosphere, and the numbers of electrons moving freely in it.

BEFORE ENCOUNTER

From leaving Earth's orbit many of these instruments have been gathering important information about space. Already they have produced significant results.

First, they traced the solar wind and its particles far from the Sun, further than ever before. They found that the wind slows down but becomes more turbulent. They also found that high energy particles emitted by the Sun include the elements sodium and aluminum. Another surprise was the discovery that the hydrogen flowing into the Solar System does not come from the direction to which the Sun and its retinue of planets is moving, but seems to flow along the plane of the Earth's orbit. There is no explanation.

Helium from the Galaxy was also detected flowing into the Solar System. But Galactic cosmic rays appear to be screened somehow by the turbulent solar wind. It stops low energy particles from coming in from the Galaxy inside the orbit of Jupiter at least.

The spacecraft's instruments looked at interplanetary particles, particularly those in the asteroid belt which might be a hazard to spacecraft. Some surprises resulted. The smallest particles declined in numbers as the Pioneer moved out from the Sun. Somewhat larger particles were evenly distributed with no increase in the asteroid belt. However still larger particles did become three times as numerous in the belt. Other instruments confirmed these results. Thus Pioneer 10 has proved that the asteroid belt does not have myriads of dangerous small particles. Instead it consists of much less numerous larger particles. It does not present the hazard to spaceflight once thought. There may be even fewer small particles in the belt than near Earth.

THE ENCOUNTER AND AFTER

In late November 1973 Pioneer 10 glides in towards the brightly colored and enormous Jupiter—passing the four small outer satellites at 25 days before closest approach, the three middle satellites at 11 days, and, in the grip of the immense gravity, the four planet-sized Galilean satellites and the tiny inner moon in a rush on the day of closest approach, December 3.

At the closest approach to 81,000 miles, Jupiter fills the black sky, an enormous yellow-orange and blue-gray-belted sphere. And six hours earlier, Pioneer begins to test the intense radiation belts while controllers on Earth anxiously await confirmation that the belts are not damaging the equipment of the spacecraft.

Low resolution pictures are taken of the five inner satellites and of Jupiter itself, while the battery of instruments probe into surrounding space, the satellites and the planet.

Spacecraft operation during the encounter are complicated by 92 minutes of round trip time for radio signals to pass back and forth and a need to send 10,000 commands to the spacecraft in the two weeks centered on closest approach.

After Jupiter, Pioneer 10 heads out of the Solar System, crossing Saturn's orbit in 1976, Uranus' orbit in 1979, Neptune's orbit in 1983, and in 1987, 15 years after launch, the orbit of Pluto, the known limit of the Solar System. Pioneer's destination among the stars of the Galaxy is then somewhere in the Zodiacal constellation of Taurus (The Bull). The spacecraft heads out from the Solar System at 25,000 miles per hour carrying a plaque that tells any intelligent species who may find it millions or billions of years from now, who sent it and from where it came.

A project of NASA's Office of Space Science, the Pioneer project is managed by NASA's Ames Research Center, near San Francisco, California. The two spacecraft are built by TRW Systems, Redondo Beach, California. The scientific instruments are supplied by NASA Centers, universities, and private industry. Tracking is by NASA's Deep Space Network, operated by the Jet Propulsion Laboratory, Pasadena, California.

STUDY PROJECTS

ONE

On the map of the Solar System, made as a project for leaflet #1 of this series, draw the path of Pioneer 10. Work backwards from the encounter on December 3 using Figure 2 as a guide to find the position of the Earth at launch. Put the path of Pioneer 11 on the map, too, using the correct positions of Jupiter and Earth for the launch and encounter dates. Remember Earth goes twelve times around the Sun when Jupiter goes around once.

TWO

If Pioneer 10 leaves the Solar System at 25,000 miles per hour 15 years hence and heads towards the stars at this constant speed, calculate how long it takes to reach the distance of the near star, Proxima Centauri, which is 4½ light years away. (A light year is the distance light, speeding at 186,000 miles a second, travels in one year). Calculate how fast a spacecraft has to travel to reach this near star in 10 years.

READING LIST

NASA SP-268, The Pioneer Mission to Jupiter (GPO $0.30), 1971.

Science News, 11 March 1972, Pioneer 10 Begins Journey to Jupiter.

Science News, 24 February 1973, The Asteroid Belt.

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